Accelerated Repair of Jointed Concrete Pavements (JCP) using Precast Concrete Panels-Colorado Experience

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Abstract

One hundred and fifty seven distressed concrete slabs were rehabilitated with precast concrete panels at 18 separate locations along the I-25 corridor north of Denver between Mead and Loveland during October and November, 2003. The purpose of this study was to document the feasibility of precast panels as a "fast track" repair alternative. The panel thicknesses ranged from 5.5 in. to 7.25 in. and panel lengths varied from 12 ft to 20 ft. The repair clusters consisted of 2-8 slabs connected by fiber glass ties. High Density Polyurethane (HDP) foam was used to stabilize and slab jack the panels to match elevations. The transverse and longitudinal joints were backfilled using joint bonding material. The majority of panels were diamond ground to ensure acceptable ride quality. The entire project was completed in fifty four days. The parameters considered to establish initial repair effectiveness include (i) construction speed and (ii) structural integrity in terms of deflection (uniformity of support.)

Background

One promising development in the area of full-depth repair of concrete pavements is the re-emergence of precast concrete pavement panels as a viable alternative to traditional cast-in-place methods. Precast concrete pavement slabs have the potential of being manufactured and installed quicker than conventional cast-in-place methods. Such panels can also be installed year-round with equivalent quality as traditional repair methods.

The potential efficacy of this method was tested in Colorado, along interstate 25 north of Denver between Mead and Loveland. The construction of these panels was accomplished during October and November, 2003. The subsequent sections of this paper detail the panel installation process, material and structural details, construction productivity and structural effectiveness.

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Research Significance

The purpose of this project is to document the feasibility of precast panels as a jointed concrete pavement repair alternative. As part of this project; (i) construction efficiency in terms of labor and installation time were documented to determine if this process can be termed as "accelerated" and (ii) structural adequacy was monitored using falling weight deflectometer.

Site Selection and Description

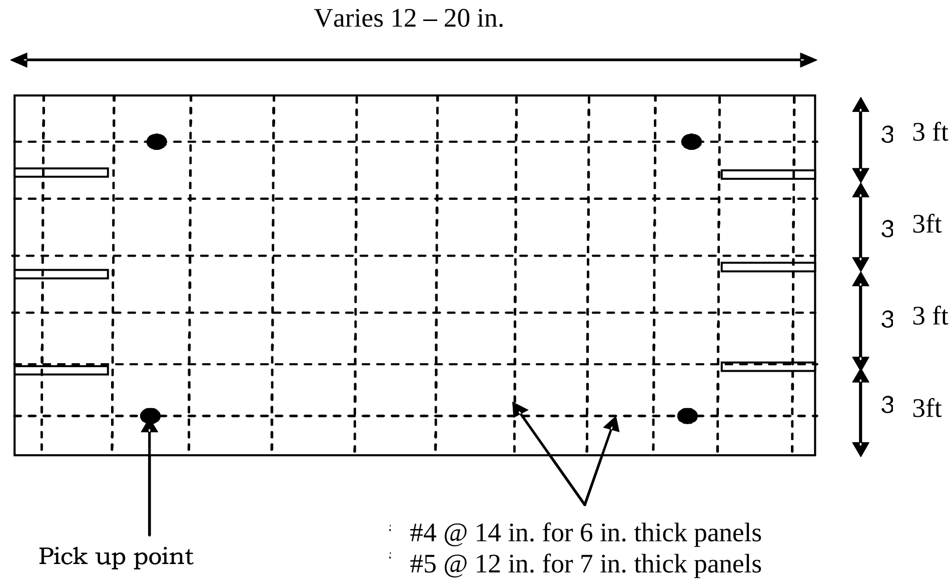
One hundred and fifty seven distressed concrete slabs were replaced at 18 separate locations along the I-25 corridor north of Denver between Mead and Loveland (mileposts 244 to 270) during October and November, 2003. The candidate sections were selected by the Colorado Department of Transportation (CDOT.) Due to large volumes of traffic, only single lane closures were permitted for construction for an eight hour period starting at 9:00 pm and ending the following morning at 5:00 am. Additionally, the construction areas were required to be open to traffic during the higher volume times.

The average annual average daily traffic (AADT) and percent trucks along the construction corridor were 45,886 and 14% respectively. This information is based on the year 2002 data (Command and Meeker, 2003.) The contractor was responsible for making all the measurements prior to the fabrication of the panels. The measurements were made along the four sides and diagonals to account for any joint skewing. Multiple pavement cores were extracted at each location to determine variations in thickness from end to end as well as near the shoulder and centerline. This dimensional information was used in fabricating the precast panels.

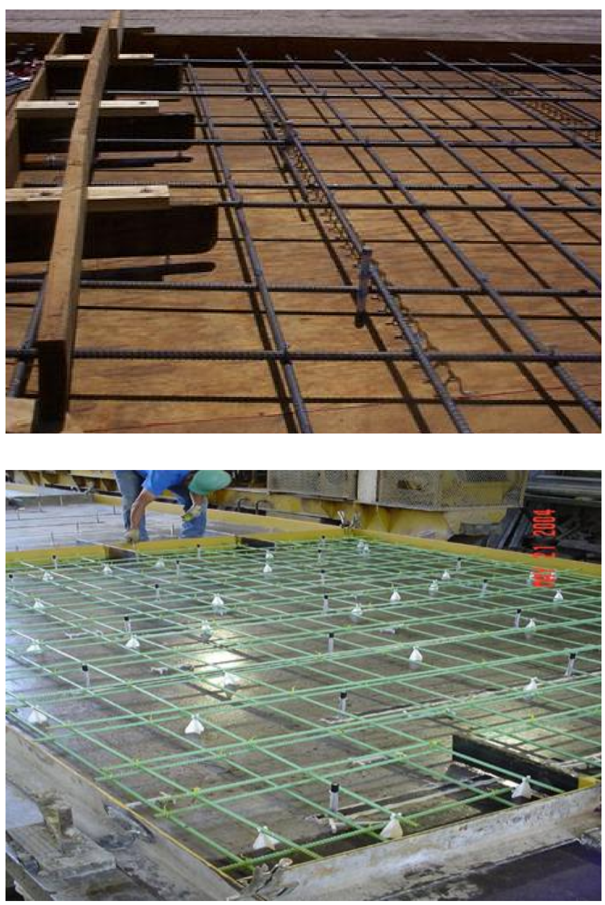
Material and Structural Details of the Panels

The precast PCC panels were fabricated by the contractor at a nearby casting yard and transported to the project site. The typical structural details of the panels are illustrated in Figure 1. The tie bar slots were placed at 36 in. on center and were formed during the panel fabrication process. The panel also consists of #4 (for the 5.5 in. thick panels) or #5 (for panels thicker than 6 in.) reinforcing steel bars. The panel lengths varied so as to match the existing pavement geometry.

The typical PCC mixture designs for this study are summarized in Table 1. The average 7- and 28-day compressive strengths were 4740 psi and 5814 psi respectively. The contractor placed approximately 25,300 ft^2 of concrete.



a) Design layout



b) Reinforcing steel placement

Figure 1. Structural details of the precast panel.

Table 1. PCC mixture designs for the precast panels

Mix Ingredients	Design, lbs
Cement	658
Water	217
Fine Aggregate	1368
Coarse Aggregate	1574
AEA	1.0 fl.oz
WRA	220 oz
HRWR	50 oz
Non Chloride Accelerator	290 oz

Figure 2. High severity corner breaks with associated spalling.

Installation Details

Prior to the removal of the selected panels a distress survey was conducted. Typical distresses observed during the survey included (i) mid panel transverse cracks with associated spalling; and (ii) joint sealant damage, spalling and asphalt patch deterioration and (iii) corner cracking. Examples of the typical distresses are illustrated in Figure 2.

The overall construction sequence is divided into two categories (i) off-site activities and (ii) on-site activities. The sequence of operation for both these categories are listed below:-

Off-Site Activities.

1. Fabrication of the precast panels; and
2. Storage of the fabricated precast panels.

On-Site Activities. The on-site activities are divided into four construction operations and they include:

1. Slab removal and base preparation
    a. Sawcutting of panel boundaries
    b. Demolition of distressed panels
    c. Removal of the distressed panels
    d. Cleaning of the exposed base
    e. Heat lancing the exposed concrete faces to remove traces of moisture.
2. Panel placement and alignment
    a. Transporting precast panels from the storage yard
    b. Placement of the precast panel into the prepared excavation
3. Precast panel elevation adjustment
    a. Drilling of injection port holes
    b. Injection of the HDP foam to adjust slab elevation
    c. Filling of voids (if any) with HDP foam to ensure uniform support under the panel
4. Joint Preparation
    a. Sawcutting of tie slots in the existing end panels to match with the slots in the precast panels
    b. Removal of all extra foam that surfaced during the slab stabilization and void filling process
    c. Air cleaning and sand blasting all tie slots to ensure good bonding
    d. Heat lance the tie slots to remove all traces of moisture
    e. Insert the fiberglass tie bars
    f. Backfill tie slots with prewashed dried aggregate
    g. Apply the polyurethane joint bonding material
    h. Seal injection ports using non-shrink grout

Slab Demolition and Removal. The perimeter of each distressed panel was sawcut. Additional transverse cuts were made to expedite the panel breaking operation. The initial breaking of concrete was done using a standard backhoe fitted with a jackhammer. An additional track-hoe was used to excavate and remove the demolished concrete. Figure 3 illustrates the slab demolition and removal process.

a) Slab demolition b) Removal of debris

Figure 3. Slab demolition process.

Base Cleaning and Preparation. The exposed concrete base layer was swept and cleaned using compressed air. In addition to the cleaning the base and joint edges were dried (to remove any traces of moisture) using a hot air lance. A secondary effect of using the hot air lance was to expedite the curing of the slab jacking foam. Figure 4 illustrates the base preparation activities.

Panel Placement and Alignment. The panels were brought to site on flatbed truck and lowered into the excavation using a 30 kip truck mounted crane. Figure 5 illustrates the panel placement process.

The precast panel elevations prior to jacking ranged from 0-3 in. below the passing lane and/or shoulder. A two part polymer was mixed and simultaneously injected through the port holes (5/8 in. diameter) to lift the precast panel. In order to achieve uniform support under the precast panel approximately 21 injection port holes were needed. However, the panels were delivered with only nine port holes. This required the installation crew to drill additional port holes on site. The polyurethane foam has a free rise density of 3.0-3.2 lbs/ft^3, with a minimum compressive strength of 40 psi (ASTM 1621.) According to the manufacturer specification the foam is expected to reach 90% of full compressive strength within 15 minutes (URETEK USA, 2001.) Dial indicators were mounted on the panel surface to monitor the change in the slab elevation relative to the adjacent pavement. The panel jacking commenced by lifting at the two corners on one side of the panel this was followed by the lifting of the slab at the other end until the elevation matched the existing roadway. In addition, the foam also served to fill in voids under the panel after the slab jacking was completed the ensured uniform support under the panel and good long term performance of the repairs. Throughout this project approximately 18,000 pounds of the two part polymer was used.

Figure 4. Base preparation activities.

a) Panel lowered into excavation b) Alignment of panel

Figure 5. Panel placement process.

Joint Stitching and Bonding. A good bonding surface was obtained by removing all excess foam from joint faces and formed stitch slots. This was accomplished by using a pavement saw to cut the foam on both sides of the construction joint. The joint faces were then sandblasted to ensure clean bonding surfaces for effective adhesion. In addition to this all surfaces were hot air lanced to remove traces of moisture. Stitch slots were saw-cut in the existing approach and departure slabs. The entire saw cutting was done in the absence of water to prevent reaction with the slab jacking foam and joint bonding material.

The fiberglass stitches were placed into the ¾ in. slot using two guides wire spacers, one at each end. The fiberglass ties are 36 in. long, 5 in. wide and 0.25 in. thick. A photograph of the tie bar is shown in Figure 6.

Dried aggregate (1/8 in.-1/4 in.) were used to backfill the stitch slots. The polyurethane foam was applied to bind the aggregates and prevent segregation. It is recommended that expansion joints be placed at 45-60 ft intervals. The expansion joints were ¾ in. wide and stitched together using the fiberglass ties.

The injection ports were sealed using a non-shrink grout. The procedure included (i) drilling out left over jacking foam; (ii) cleaning the surface of the concrete for proper adhesion; and (iii) placing of the grout. Figure 7 illustrates a group (cluster) of precast panels consecutively placed.

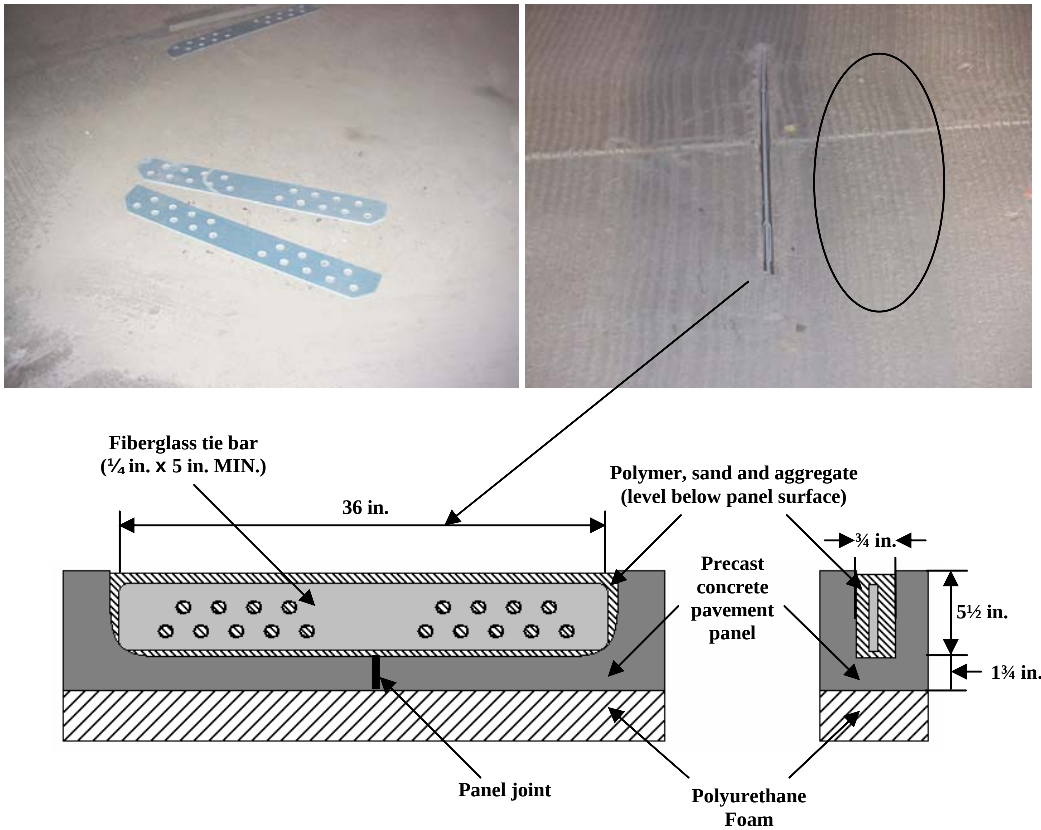


Figure 6. Structural details of the Fiber glass stitches.

Figure 7. Completed cluster of precast panels.

Construction Productivity

The construction productivity metrics include the documentation of the (i) time to complete the installation of panel cluster; (ii) list of possible concurrent activities; (iii) various equipment used for the installation of panels and (iv) panel installation crew size. Table 2 summarizes a list of equipment needed to successfully install precast panels.

Figure 8 shows the relationship between average elapsed time (start to finish) per panel (within a cluster) and number of panels in a cluster. From this plot it can be surmised that as cluster size increases the installation productivity improves. Figure 9 highlights the contractor's improving comfort level (in terms of production efficiency) with the project progression. During the initial stages of the project the contractor was installing clusters with only 1 to 2 panels over an eight hour construction window. After day 20 the production rate increased to 4 to 8 panels per cluster. The increased productivity was a result of multitasking (of activities.) In specific the changes made by the contractor included: (i) reduction in panel demolition time; (ii) concurrence in the panel demolition, base preparation activity and installation of new panels; and (iii) providing an additional applicator for joint bonding operations. The advantages of incorporating concurrent activities in the construction regime are illustrated in Figure 10. As the proportion (based on overall time/panel) of multitasking increases the number of panels that can be installed within the allowable construction window increases.

Table 2. List of Equipment used for panel installation

Equipment Type	Application in the Installation Process
Ingersoll L6 light plant	Work area lighting during night closures
CAT 416 back- hoe w/jackhammer	Initial break up of concrete to be removed
CAT 325B track-hoe	Excavation of concrete to be removed
Two haul trucks	Haul concrete debris
Ingersoll 185 compressor	To remove debris from work area. Clean joints and stitch slots
Two pavement saws	To cut stitch slots in adjacent pavement slabs
Sandblasting equipment	To prepare jints and stitch slots
Hot air-lance	To prepare joints prior to bonding
Propane weed burner	To dry and heat aggregates used in the joint bonding operation
Portable concrete mixture	For aggregate mixing. Also used for mixing cement mortar for backfilling

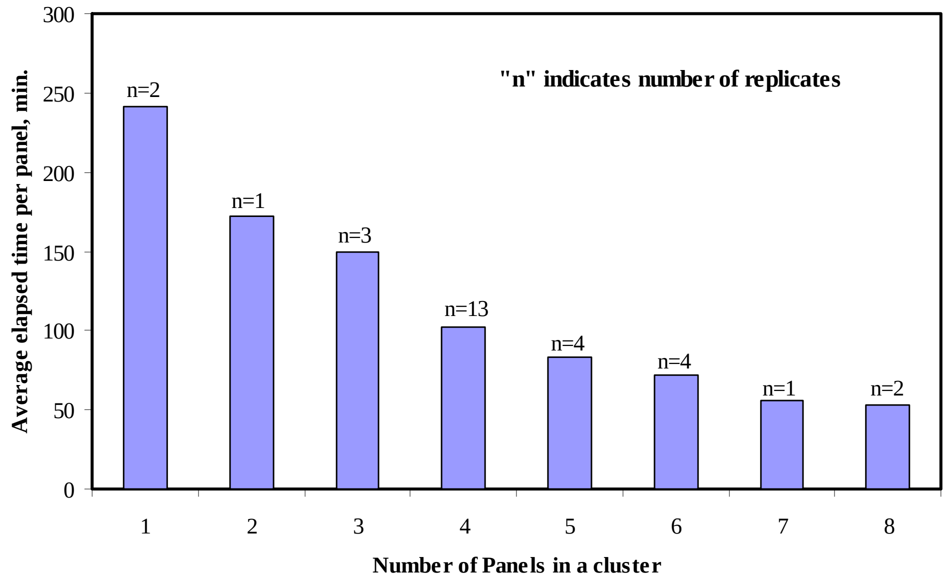


Figure 8. Relationship between average elapsed time per panel and the number of panels.

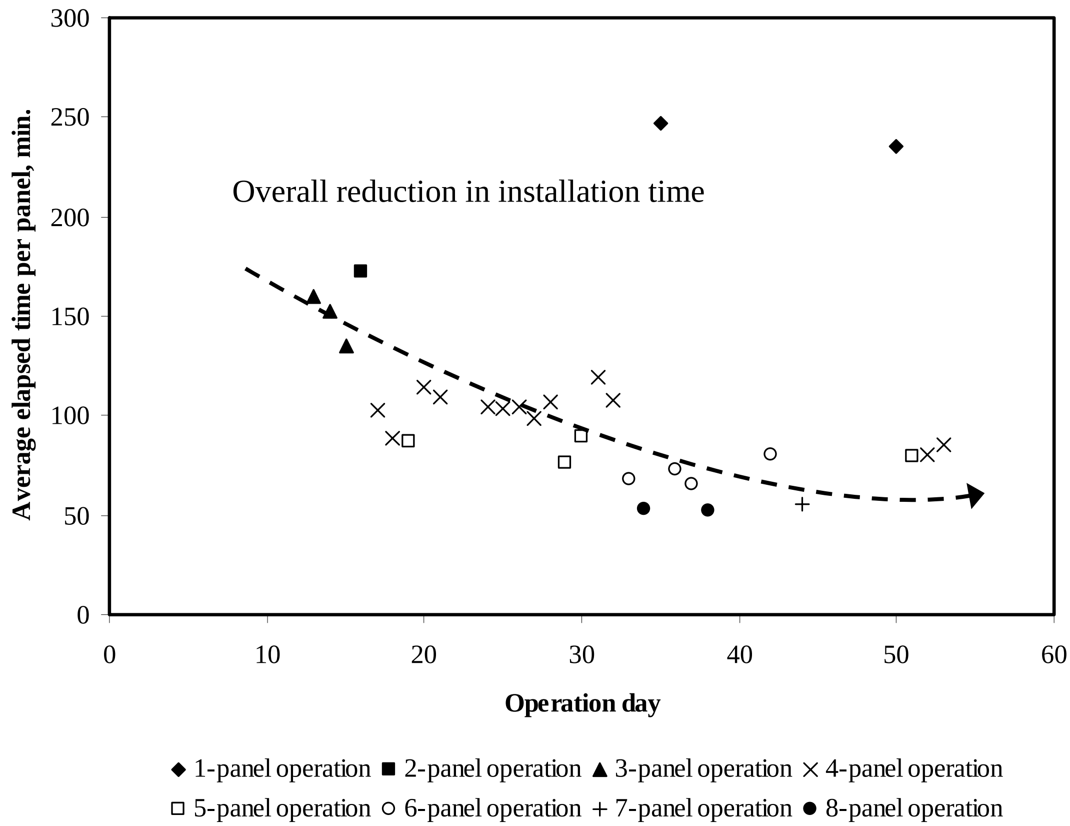


Figure 9. Increased productivity with project progression.

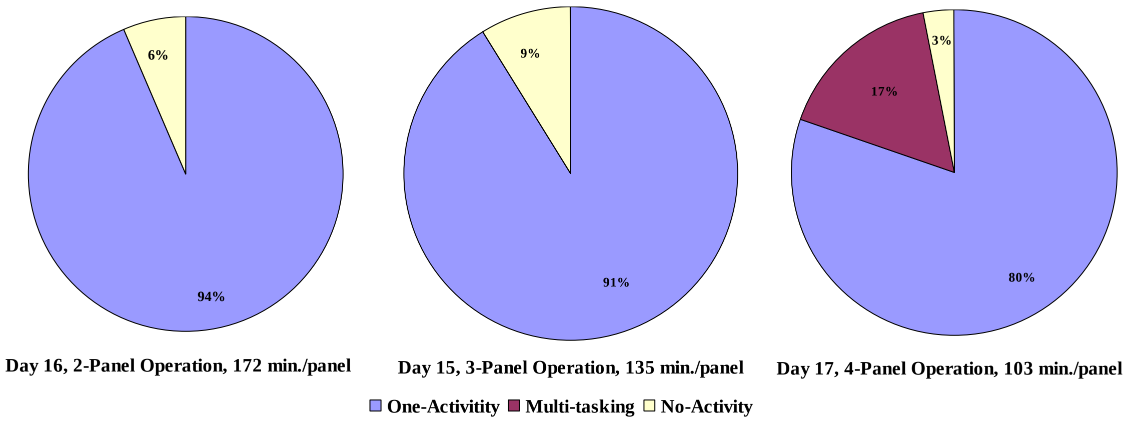


Figure 10. Illustration of advantages of incorporating concurrent activities.

Structural Effectiveness and Performance

Falling weight deflectometer (FWD) tests were conducted on 81 panels. These sites represented various panel cluster sizes, precast panel thicknesses and construction times. The testing protocol adopted to determine the intial structural effectiveness is illustrated in Figure 11. Testing was conducted between 9:00 pm and 5:00 am. The time, air temperature during FWD testing ranged from 58 to 68^{o}F. Data from positions 1 and 3 were collected to monitor joint deflection. Position 2 deflection data were used to monitor edge support, whereas deflection data from position 4 provided information about mid panel support. Joint load transfer efficiency was not computed as the transverse joints were fitted with ties and not dowel bars.

Figure 12 illustrates the peak (mid slab) average deflections measured at location 4 for 81 panels. The thickness ranges from 5.5 in. to 7.25 in. The peak (average) deflections range from 5.6 to 12.1 mils. On average the thinner panel sections experience higher deflections than thicker panels. Figure 13 illustrates the peak (edge) average deflections measured at location 2 on the precast panels. The relationship between the deflection magnitude and slab thickness is similar to the one observed in Figure 12. Figures 14 and 15 illustrate the peak joint deflections. *Note that all deflections shown in Figures 12 through 15 are normalized to a 9-kips load.* The error bars indicate the scatter in the measured deflection data. This scatter can be attributed to the possible variability in support under the panel in the vicinity of the joint. Based on the data presented in Figures 14 and 15 the following observations can be made:

- On average peak deflections at joints for thinner slabs are higher than those for thicker slab.
- Irrespective of slab thickness, joints between the precast panels and the existing slab (approach or departure) deflect less than the joint between two new precast panels. The deflection data scatter (as seen in the error plots) is more for joints between two new precast panels than for joints between the existing slab and the precast panel. It is premature to speculate on reasons for this differential behavior.

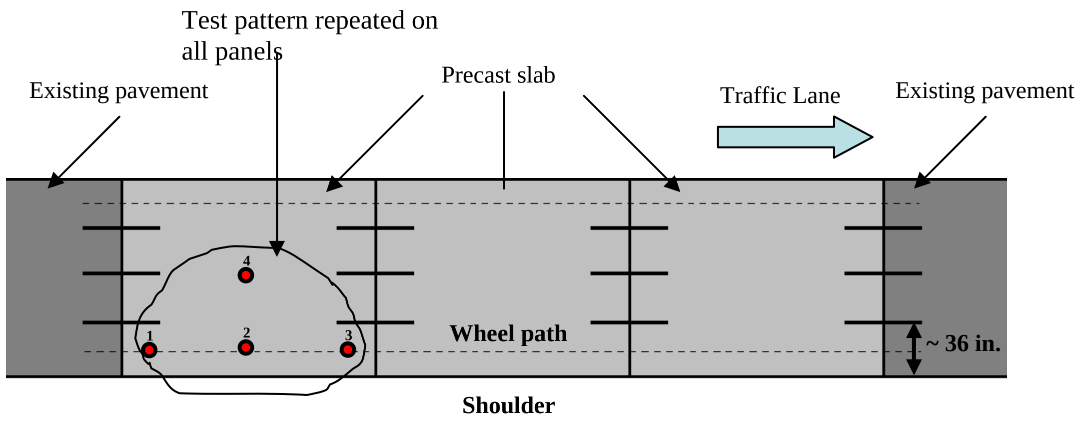


Figure 11. FWD Test Pattern.

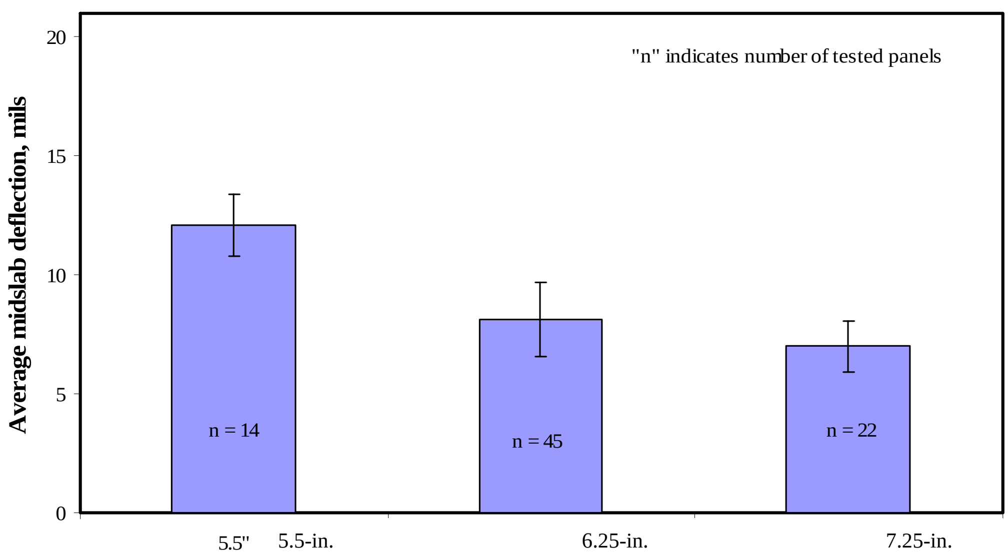


Figure 12. Average midslab deflections as a function of slab thickness.

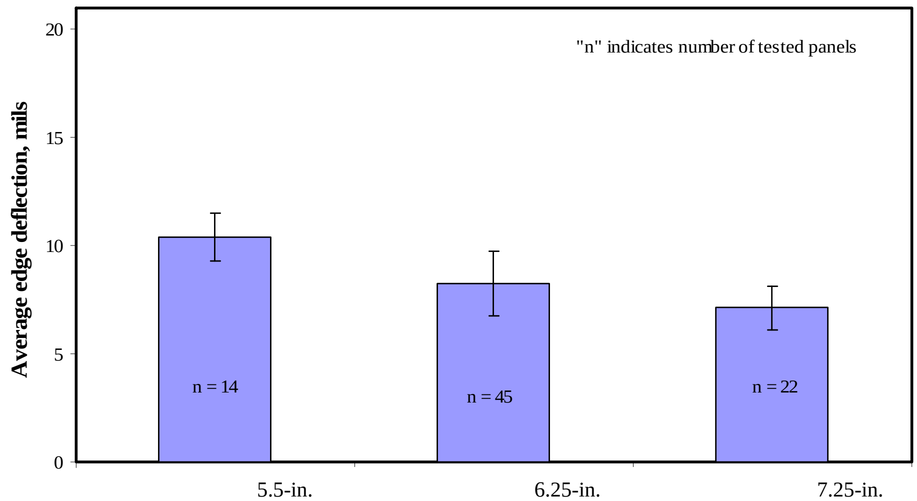


Figure 13. Average edge deflections as a function of slab thickness.

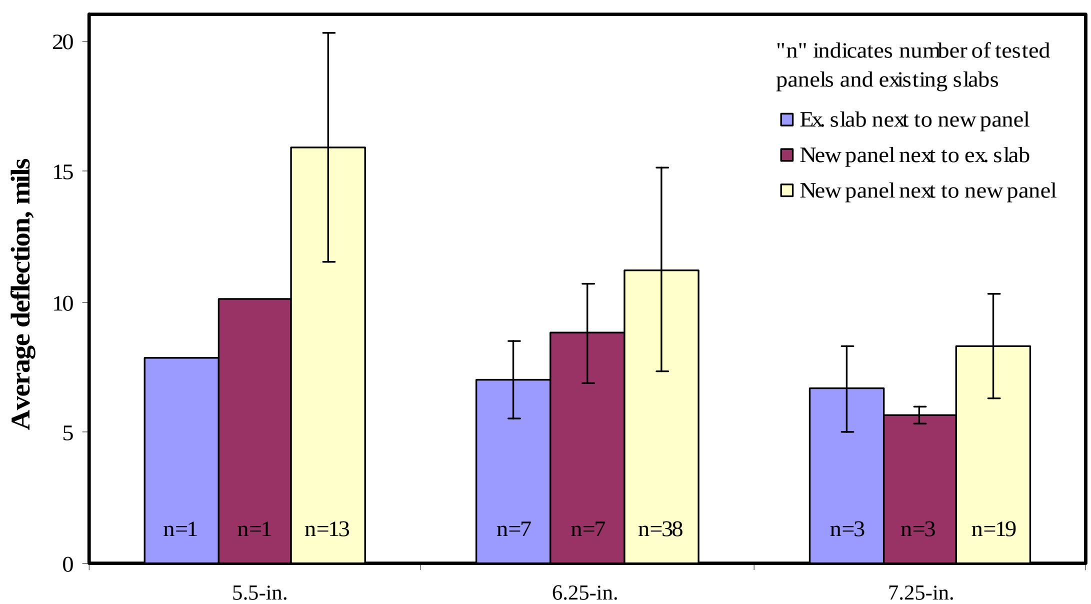


Figure 14. Average joint deflections (approach) as a function of slab thickness.

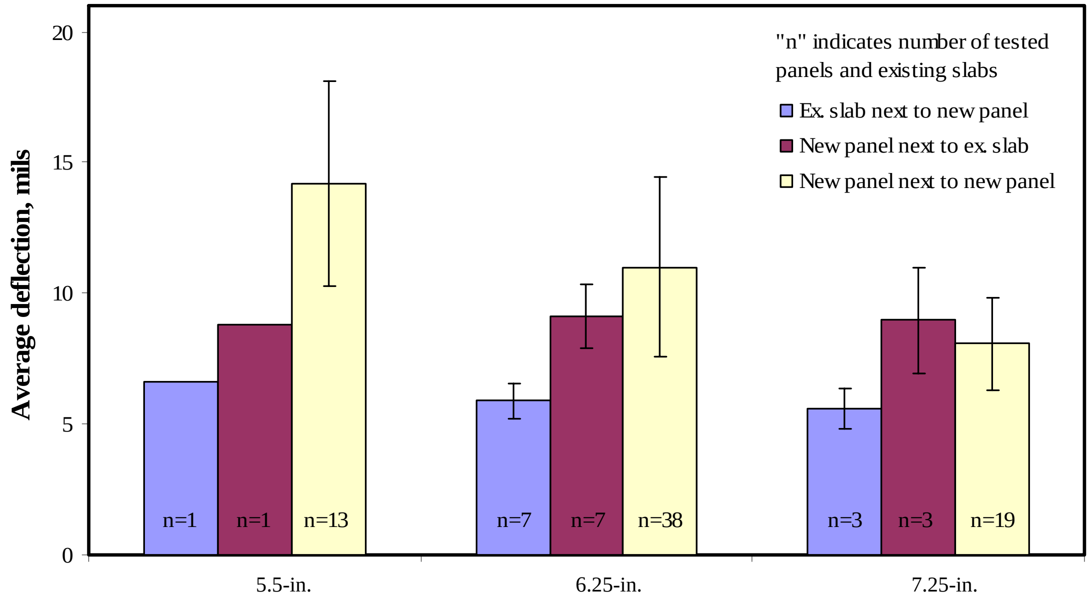


Figure 15. Average joint deflections (leave) as a function of slab thickness.

The distress survey of the panels revealed the presence of low to medium severity cracks in approximately 20% of the precast panel slabs. The majority of these cracks were in the vicinity of the fiber glass stitches. A typical crack pattern is illustrated in Figure 16.

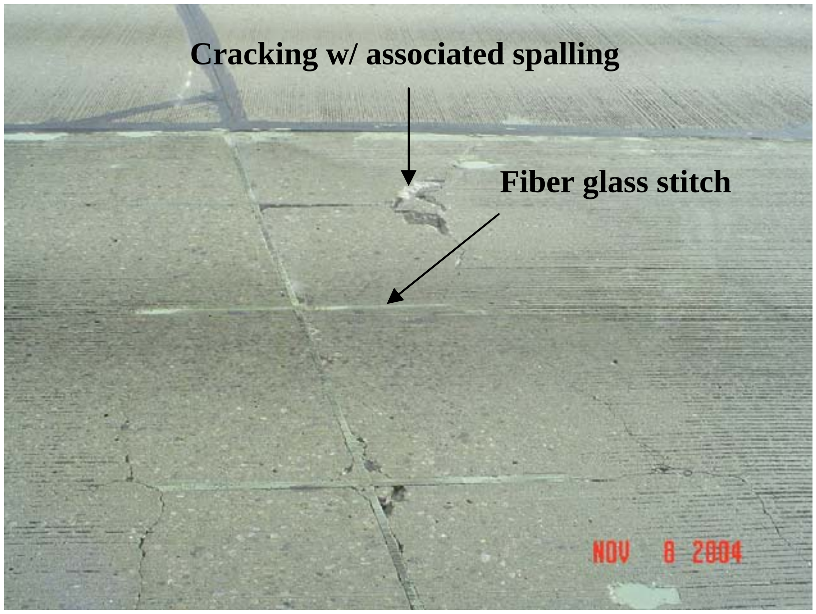


Figure 16 Typical crack patterns

The possible reasons for this premature failure include: (i) non-uniform support in the vicinity of the stitches resulting in tensile stresses at the top fibers of the panel; (ii) inadequate slab thickness to carry the axle loads; and (iii) longer effective slab lengths due to joint ties.

Lessons Learned

The rate of panel installation is highly dependent on the level of multitasking and the execution of concurrent activities. Another parameter that has an impact on productivity is the number of panels per cluster. As indicated in the paper, the average elapsed time per panel was reduced on days when cluster sizes were greater than 4 panels.

The slab stabilization and void filling time can be reduced in the future if the precast panels came with the requisite number of injection ports from the fabrication plant.

During the earlier stages of the project the contractor realized that the presence of moisture (due to saw cutting, ambient humidity and joint bonding aggregate) impedes the curing of the polyurethane foam. Based on this observation early on in the project all exposed concrete surfaces were dried using a heat lance and also all joint bonding aggregate were dried prior to installation.

Acknowledgement

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Disclaimer

The published material represents the position of the authors and not that of the Colorado Department of Transportation.

References

Command, M., and Meeker, B. *Maintenance Project MTCE 04-040*, *Report of Precast Concrete Replacement Panels on I-25, Draft Report*, Colorado Department of Transportation, Denver, Colorado, Fall 2003.

URETEK USA, *URETEK USA Engineering Manual*, 7th Printing, Tomball, Texas, September, 2001.